Meetings

The Planet Jupiter

In 1955 it was discovered that Jupiter is one of the strongest sources of radio waves in the heavens. The cause and nature of these radio signals was one of the major topics of discussion at a conference held 16 and 17 October at NASA's Institute for Space Studies, New York, to consider the properties of Jupiter.

One set of signals broadcast by Jupiter resembles the radiation emitted by the electrons in the Van Allen belts. It is generally believed that these signals are produced by charged particles that are trapped in a Jovian magnetic field.

Jupiter's Van Allen belt was first detected from measurements of the polarization of the signals, made by Leland David, Jr., and other scientists at California Institute of Technology with the 85-foot disk at Owen Valley. They found that the radiation was linearly polarized. The only known sources of such polarized radiation in nature come from synchrotron radiation, in which the electrons spiral around magnetic lines of force and radiate at right angles to these lines of force.

In presenting the results of the investigation, David Morris (California Institute of Technology) and D. B. Chang (University of California, San Diego) reported that the Van Allen belt of Jupiter is several times as intense as the Earth's and is held in place by an extremely strong magnetic field.

The radiation emitted by the trapped electrons has frequencies between 3000 and 10,000 megacycles per second, corresponding to wavelengths of 20 or 30 centimeters in the decameter region. From the frequency, Chang derived the result that the strength of the magnetic field is 1 gauss. Near the surface of the planet the strength is probably much greater—about 100 gauss. This is several hundred times stronger than the Earth's magnetic field at the surface.

Interferometric observations on the decimeter radiation, and the corroborating observations and interpretations of other groups, were presented by Morris. According to these results, the decimeter radiation comes from equatorial zones in the upper atmosphere about 3 radii from the center of the planet.

Jupiter emits other radio signals which are more puzzling than the decimeter radiation. These are radio noise storms—occasional bursts of radio signals in the decameter region with frequencies of the order of 1000 megacycles per second and wavelengths of 10 to 30 meters.

The decameter radio storms are extremely intense, equivalent to repeated explosion of hydrogen bombs at the rate of one every second, or to an energy release of 1 million tons of TNT per second. In terms of terrestrial wind systems, the energy released is equivalent to one hurricane or small cyclone per second.

Until recently, this radiation was believed to stem from lightning strokes produced in Jovian thunderstorms, but it was the consensus of the conference that this is not the correct explanation. Leona Marshall (New York University) noted that radio waves generated by atmospheric lightning discharges would cover a broad range of frequencies, whereas the decameter waves are confined to a narrow range. It was agreed that the storms must occur in the Jovian ionosphere at high altitudes, and not at the low altitudes which are the seat of weather disturbances.

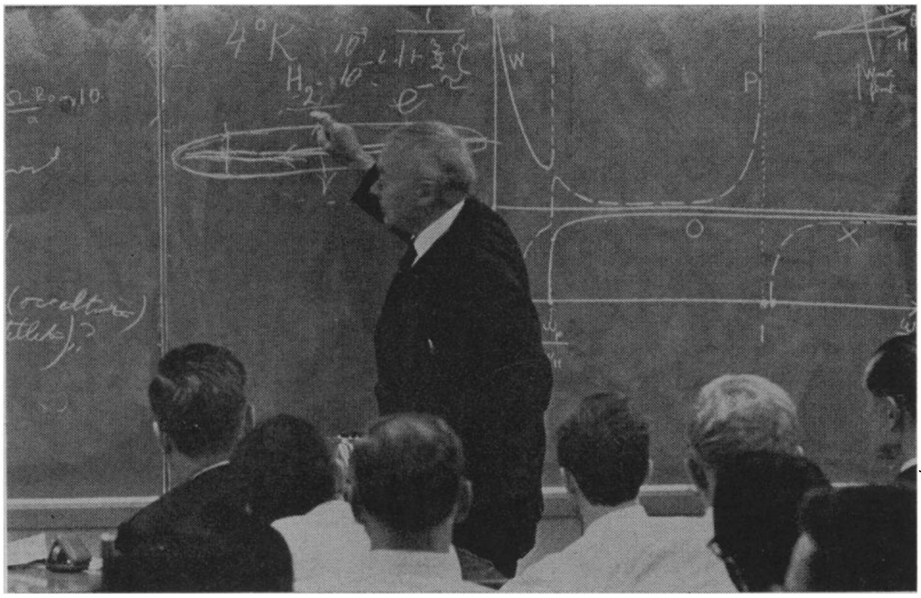
Several new ideas were presented to replace the theory of lightning discharges. The intensity of the decameter radiation varies with time and has an extremely complicated pattern. In duration it ranges from times of the order of hundredths of a second to the entire duration of the storm, which may be several hours. The fact that the decameter radiation is heard only sporadically and with rather abrupt beginnings and endings suggests that it may be emitted in sharply focused cones.

This idea is strongly supported by the fact that a rotation period can be observed within which certain longitude regions on the surface of Jupiter appear to radiate actively while others appear to be essentially dead. Moreover, at least at frequencies of 20 megacycles or more per second, the Jovian radiation is emitted in a three-part pattern with a very strong central element and two weaker lobes which flank the central one at about 90 degrees. It may be significant that the major lobe coincides with the orientation of the magnetic axis.

The Larmor frequency of rotation in the magnetic field is an important factor in theories of the origin of these storms. Leona Marshall suggested a spin-flip transition that is stimulated by hydromagnetic shock waves. George Field (Princeton University Observatory) proposed an "antisynchrotron" mechanism based on amplification of a weak electromagnetic disturbance moving along magnetic field lines and encountering particles spinning at a similar local gyro frequency. According to his theory, the electrons lose energy to the electromagnetic waves; this is the reverse of the operation of a synchrotron.

James Warwick (National Bureau of Standards, Boulder, Colorado) proposed a picture in which the radiation is emitted by the spiraling electrons at the Larmor frequency in the regions where the local plasma frequency is of about the same value—a Cerenkov cyclotron mechanism. But in this model, as in the others, the radiation is generated by particles spiraling in along magnetic force lines toward the poles. Thus, all interpretations were attempts to work out detailed pictures of the way in which a magnetic dipole would so orient the field lines as to generate the radiation either directly or by reflection from the top of Jupiter's ionosphere.

The intensity of the radiation belts and their time variations suggest a frequent and substantial unloading of



At the conference, Ernst Opik, research professor in the University of Maryland's department of physics and astronomy, discusses the composition of Jupiter.

trapped-particle energy into the atmosphere of Jupiter. In this case, very strong auroras should occur on Jupiter. A search for Jovian auroral emissions would be an interesting project in future observations of the planet from the ground or from space.

Earlier ideas about the atmosphere on Jupiter were revised during the meeting. R. M. Gallet (National Bureau of Standards) said that older models of the Jovian atmosphere neglect the changes produced by the condensation of ammonia and water vapor. Making allowance for the heat released in this condensation, he calculated a lower temperature and a higher density in the deep atmosphere of the planet than had been believed likely. He estimates the temperature of the surface of Jupiter to be 500°C or higher.

Gallet also suggested that the atmosphere near the surface consists of gaseous ammonia, with ammonia rainstorms above, and then a cloud deck of ammonia ice crystals, 30 miles thick. There should be water clouds a few miles below the ammonia clouds.

So little is known about Jupiter that it is not even clear whether it has a well-defined surface. The base of the Jovian atmosphere may blend imperceptibly into a gaseous and then a liquid region of gradually increasing density. However, it was the consensus of the conference that there is a surface of solid hydrogen, several hundred miles below the clouds.

Such a surface would not be expected to have high structural strength, but there might be some elevations or depressions. The elevations would be remnants of catastrophic effects such as impact with large meteorites or asteroids. The depressions might be produced by processes such as were originally suggested by Gallet: if Jupiter's surface represents a phase transition that is temperature-sensitive, then a local mechanism feeding sufficient heat to the surface in a particular region could cause a substantial depression of the phase boundary nearby.

This general picture of the Jovian surface may lead to an explanation of Jupiter's most remarkable feature, the Great Red Spot, an oval region 30,000 miles long and 7000 miles wide in the southern latitudes of the planet. The Red Spot was first seen by the Italian astronomer Cassini, in 1655, and it has been in view most of the time since then. Over the past century its latitude has remained nearly constant.

Raymond Hide (Massachusetts Institute of Technology) suggested that the Red Spot is the top of a huge column of gas which remains stationary above a major mountain range or depression on the surface of the planet. In laboratory experiments with rotating fluids Hide has been able to produce such a column above an elevation.

The interior of the planet was discussed by Wendell C. DeMarçus (University of Kentucky). DeMarcus presented calculations which indicate that 80 percent of Jupiter is hydrogen, solidified under the gravitational force of the planet. The remainder is helium

Jupiter's Great Red Spot, taken through the 200-inch telescope [Mount Wilson and Palomar Observatories].

and heavier elements in much smaller amounts.

If hydrogen constitutes 80 percent of Jupiter's mass, there will be no fundamental difference between the deep interior and the outer layers, except that the pressure near the center will compress the hydrogen gas into a metallic phase.

Until recently Jupiter's interior had been believed to be relatively cold. This conclusion was based on the assumption that the interior consists of metallic hydrogen, a good conductor of heat. However, it now seems likely that there is a sprinkling of impurities in the interior, whose effect would be to reduce the thermal conductivity and raise the temperature.

George Field calculates the temperature at the center to be 1000° to 10,000°C. The existence of a strong Jovian magnetic field may be related to this result, because one of the theories for the origin of planetary magnetic fields suggests that they arise through convective flows in a liquid metallic core, simulating the action of an electric generator. For the flow to occur in the core, a high temperature is essential.

H. Spinrad (Jet Propulsion Laboratory) gave an important paper on his recent measurements of high dispersion spectra in Jupiter. He found that the ammonia lines occur, not with a tilt corresponding to the rotation of the planet, but with a tilt suggesting Doppler shifts and corresponding to a much slower rotation. It appears, according to these results, that some intermediate level of the atmosphere above the clouds is not rotating with the planet but is rotating 7 or 8 kilometers per second more slowly. That means a supersonic backward flow or wind, relative to the surface, of 7 kilometers per second.

One point was made very clearly at the conference: it is regrettable that so little time has been made available for planetary spectroscopy on the major telescopes.

Approximately 40 astronomers and physicists took part. The organizers were Harlan J. Smith and Rupert C. Wildt of Yale University Observatory and A. G. W. Cameron of the Institute for Space Studies. The institute was host to the conference.

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